

# 2D Motions Response Analysis of Floating Offshore Wind Turbine with Various Barge Shapes

Faisal Mahmuddin<sup>1\*</sup>, Nurhalim Dwi Putra<sup>1</sup>, and Syerly Klara<sup>1</sup>

<sup>1</sup>Department of Marine Engineering, Faculty of Engineering Hasanuddin University, 92171 Gowa South Sulawesi, Indonesia

**Abstract.** Indonesia has the potential to develop floating wind turbines at sea. Therefore, its movement response needs to be analyzed to ensure that the turbine works properly. This research aims to determine the floating offshore wind turbine barge's movement response with different floater shapes to regular waves from three different directions (0°, 45°, 90°). The movement response of the floating wind turbine was analyzed using the diffraction and radiation analysis methods in Ansys Aqwa. The research results include the RAO curve for the structure in a couple of two degrees of freedom (heave-pitch) combined with 2-dimensional analyses. The motion response of the floater cube has a maximum value heave motion 0.999 m/m and pitch motion 2.228 °/m, and the cylindrical shape has a heave motion 1.132 m/m and pitch 10.050 °/m. Lastly, the octagonal has a heave motion 1.010 m/m and pitch 2.565 °/m. The shape and volume of each model affect the response value obtained. The simulation results in this paper can provide considerations in selecting the right floater shape to be used as a wind turbine floater foundation.

## 1 Introduction

Indonesia has an advantage in developing floating wind turbines at sea, especially in the East Nusa Tenggara region, which is the region with the largest sea wind energy potential in Indonesia. The development of offshore wind energy is a pressing modern energy issue, driven by the need to find new sources of electricity and avoid the use of fossil fuels. In fact, the environmental impact of offshore wind turbines tends to be lower [1].

According to data from [2], Indonesia has a wind energy potential of 60,647 MW spread across 34 provinces. The province with the greatest potential is the East Nusa Tenggara (NTT) region, with a potential of 10,188 MW. So, the offshore floating wind turbine for this research area was chosen to be developed in the North Sawu Sea area because this area has great wind energy potential based on research data from [3].

Barge-type floating wind turbines present advantages with their ability to operate in deep and wavy waters, reaching depths of more than 100 meters. Current advantages can be seen in the European region, especially in the European North Sea, the Baltic waters, the Irish Sea,

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\* Corresponding author: [f.mahmuddin@unhas.ac.id](mailto:f.mahmuddin@unhas.ac.id)

and the British Sea area, which currently has the largest offshore wind turbine capacity with annual energy production >800 GWh and offshore wind turbines with a capacity of 300 MW from 100 turbine units currently operating in the British sea area [1]. The movement of the floating wind turbine structure when at sea is influenced by environmental conditions, such as currents and winds at sea. Therefore, it is necessary to analyze the loads acting on the floating wind turbine structure. The analysis aims to obtain the character of the dynamic response and identify potential loads and instabilities that can damage the design shape of the barge. There are several debates and studies around the world about the transition depth when a floating platform is more economical than a turbine installed on piles to the seabed. However, it is clear that when the water depth is more than 100 m, the floating floater concept is the most cost-effective solution [4].

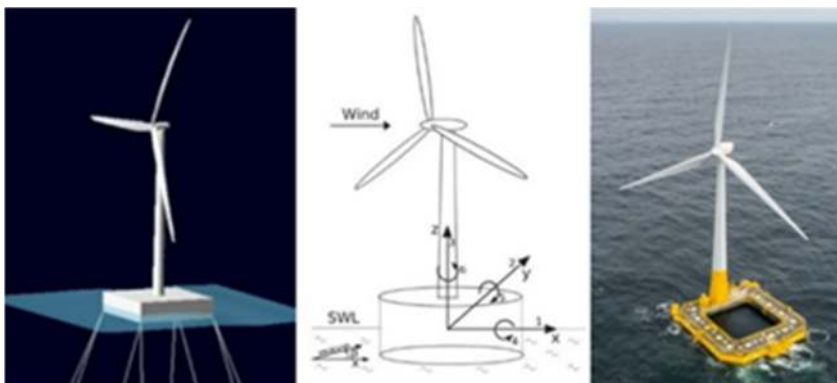
In order to decide an optimal shape, the performance of various shape needs to be compared. Example of shape optimization has been conducted by previous research in [5, 6]. The present study aims to analyse the 2D motion response of various floater shapes which are cube, cylinder, and octagon shapes. The main performance measured is the response amplitude operator (RAO). Only 2D coupled motions were considered heave and pitch motions. 3 waves directions were computed and analysed which were head wave (0°), quartering wave (45°), and beam wave (90°). Computational results from 2 software, which were Ansys and Maxsurf software, were compared to ensure the reliability of the results.

## 2 Literature Study

For the scientific reason behind the step in this research, the general theories are used, namely those concerning floating wind turbines, the shape of floater barges, and heave-pitch coupled motion response.

### 2.1.1 Floating Offshore Wind Turbine Barge Type

A floating wind turbine is an offshore wind turbine installed in deep waters, using a floating structure as its base support. This concept allows for installing wind turbines in locations far from the shore, where wind energy potential is greater. The difference between a floating wind turbine and an onshore wind turbine lies in their support systems. Onshore wind turbines use a foundation structure embedded in the ground to a certain depth, while floating wind turbines use mooring lines connecting the platform to the seabed. According to [7], support structures for offshore wind turbines come in various shapes and models, depending on water depth, turbine size, geotechnical aspects, and environmental conditions.



**Fig. 3.** Forms of floating wind turbine floater type barge

A barge achieves stability using distributed buoyancy, taking advantage of a large water plane area. A catenary mooring system is used for barge platforms. This also functions to place the structure as a floating platform for wind turbines. However, the use of barge-type floaters is limited by several issues, such as the size of the system, high bending moments at the base of the tower, dynamic movements induced by waves, and accelerations related to nacelle loads and waves.

Offshore wind turbine floating structures typically consist of pontoons or platforms equipped with a ballast system, keeping the turbine stable on the water's surface. Several types of floating structures are used, such as semi-submersible platforms, pontoon platforms, spar platforms, or tension leg platforms filled with water or other ballast materials to maintain balance. Floating wind turbines efficiently and economically capture energy from offshore wind resources. Turbines mounted on floating foundations are part of this concept, enabling power generation in deep waters where fixed-bottom turbines are less economically feasible. The main advantage of floating wind turbines is their ability to operate in deep waters with higher wind speeds compared to coastal areas. Additionally, floating wind turbines are more flexible in terms of placement and can be transported to hard-to-reach locations.

One of the current floater models that has been developed is the ITI Energy Barge model, which has a rectangular shape. The ITI Energy Barge is an initial barge concept developed by the Department of Naval Architecture and Marine Engineering at the University of Glasgow and Strathclyde under contract with ITI Energy [8]. The barge is square-shaped and balanced with seawater to achieve a normal draft. This model is suitable for use in bays and calm seas [7]. The platform is designed to be cost-effective and easy to install on-site. Floating Offshore Wind Turbine (FOWT) technology uses support structures resembling offshore buildings. The ITI Energy Barge has a unique and futuristic design, with a cube shape and precise dimensions. This cube shape is not only aesthetic but also functional. The cubic structure provides high stability on the water's surface, allowing it to withstand various sea conditions. Cubic floaters generally have a simple and efficient shape, with flat sides and pointed ends. This makes them easy to produce and manage during the installation process at sea.

Another barge model wind turbine currently being developed and installed on a platform is known as the "MIT/NREL Shallow Drafted Barge (SDB)." This barge has a cylindrical shape. The structure considered to have the lowest cost after initial consideration is the barge concept. This concept was then developed into the Shallow Drafted Barge (SDB) by the Massachusetts Institute of Technology (MIT) and the National Renewable Energy Laboratory (NREL). This pontoon type has a long cylindrical shape with a specific diameter [9]. A cylindrical shaped pontoon is an effective and reliable support structure option for floating wind turbines. Its simple design and curved surface provide a wider water dispersion area around it. The curved shape also allows water to flow more smoothly around the curved cross-section of the cylindrical floater, enabling better water flow around the floater.

The octagonal floater shape, which is also a new innovation model, is the octagonal shape. This shape is generally similar to a square but has flat surfaces at the four corners. One of the other wind turbine models currently using the octagonal shape is the Floatgen turbine model in France and Hibiki in Japan. This new octagonal floating foundation model was presented at the Grand Renewable Energy Conference in 2014. Since then, floating wind turbines have been built, tested in the port, and will soon be deployed off the coast of France. The Floatgen floating wind turbine is the first turbine project, and Hibiki is the second, developed by BW-Ideol. Due to the inherently innovative nature of the project, several new concepts were introduced and tested [10]. This shape is also similar to other barge-type models, having a symmetrical surface shape, thus providing a balanced and even main deck surface area.

### 2.1.2 Response Amplitude Operator

Response Amplitude Operator (RAO) is a parameter used in the analysis of a system's motion response to environmental loads such as wind, waves, or currents. RAO describes the relationship between the system's response amplitude and the amplitude of the environmental load at a specific frequency.

The motion of floating structures in response to sea states requires the transfer function for each frequency component of regular wave loads used to describe the motion response of the structure. The Response Amplitude Operator (RAO) is defined as the ratio  $\zeta_a =$  amplitude of the floating structure's motion for translation in units of meters (m) and rotation in units of degrees ( $^\circ$ ) to  $\zeta_a =$  wave amplitude (m). The RAO value can be found using the following equation [11].

$$\text{RAO} = \frac{\zeta_a}{\zeta_a} \tag{1}$$

where,

- $\zeta_a =$  motion structure amplitude (m,  $^\circ$ )
- $\zeta_a =$  wave amplitude (m)

### 2.1.3 Heave-Pitch Coupled Equation of Motion

The platform will naturally heave and fall due to the incoming waves. However, there is no guarantee that these two things will be independent. Therefore, it is necessary to consider these movements together. In the book Dynamics of Marine Vehicles according to [12], the equations for the heave-pitch motion are written in Equations (2) and (3).

$$(m + A_z)\ddot{z} + b\dot{z} + cz + d\ddot{\theta} + e\dot{\theta} + h\theta = F(t) \tag{2}$$

$$(I_{yy} + A_{yy})\ddot{\theta} + B\dot{\theta} + C\theta + D\dot{z} + Ez + Hz = M(t) \tag{3}$$

$$z = \text{Re}\bar{Z}e^{i\omega_e t} = \text{Re}Z_a e^{i(\omega_e t + \delta)} = Z_a \cos(\omega_e t + \delta) \tag{4}$$

$$z = \text{Re}\theta e^{i\omega_e t} = \text{Re}\theta_a e^{i(\omega_e t + \varepsilon)} = \theta_a \cos(\omega_e t + \varepsilon) \tag{5}$$

where,

- $m =$  structure mass (Ton)
- $a_z =$  added mass heaving (Ton)
- $b, B =$  damping coefficient heaving, pitching
- $c, C =$  restoring force coefficient heaving, pitching
- $d, D =$  inertial moment coefficient heaving, pitching
- $e, E =$  damping coefficient heaving, pitching
- $F =$  exciting force (N)
- $I_{yy} =$  moment of inertia of the ship in pitching motion (kg. m2)
- $A_{yy} =$  added mass pitching (Ton)
- $M =$  exciting moment (N)

From Eqs. (2) and (3), we can then obtain the equation form for the coupled heave-pitch motion response. The combined motion equation for heave and pitch can also be expressed in a matrix format like Equation (6).

$$\begin{bmatrix} m + m_{zz} & m_{z\theta} \\ m_{\theta z} & I_{yy} + I_{\theta\theta} \end{bmatrix} \times \begin{bmatrix} \dot{z} \\ \dot{\theta} \end{bmatrix} + \begin{bmatrix} N_{zz} & N_{z\theta} \\ N_{\theta z} & N_{\theta\theta} \end{bmatrix} \times \begin{bmatrix} z \\ \theta \end{bmatrix} + \begin{bmatrix} C_{zz} & C_{z\theta} \\ C_{\theta z} & C_{\theta\theta} \end{bmatrix} \times \begin{bmatrix} z \\ \theta \end{bmatrix} = \begin{pmatrix} F_z(\omega, \omega_e)e^{j(\omega_e t + \psi)} \\ \bar{M}_\theta(\omega, \omega_e)e^{j(\omega_e t + u)} \end{pmatrix} \tag{6}$$

where,

$Z_a$  = amplitude of heaving motion (m)

$\theta_a$  = amplitude of pitching motion ( $^\circ$ )

$\delta$  = heaving motion phase when the wave is at point of CG ( $^\circ$ )

$\varepsilon$  = pitching motion phase when the wave is at point of CG ( $^\circ$ )

$m$  = structure mass (kg)

$z$  = amplitude of heave motion (m)

$\theta$  = amplitude of pitch motion ( $^\circ$ )

$N$  = pitch damping coefficient

The above equations show that the motion of a couple occurs through hydrodynamic and hydrostatic action. All mass additions and damping coefficients depend on the frequency of oscillation. Moving through water is different from moving through air. This is partly because water is denser and more viscous than air (i.e. damping is increased). This extra force required appears in the equations of motion as an additional mass of the object known as mass addition.

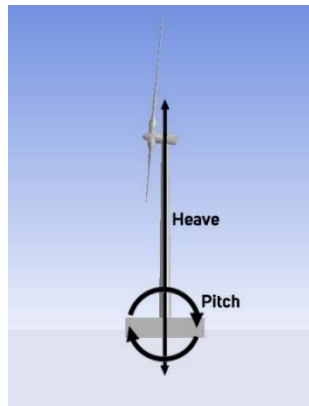


Fig. 4. Two degrees of freedom with 2 Dimensional analysis

### 3 Methods

Generally, several steps were conducted to complete this research, including determining the area for the sea location used, collecting information from literature studies, collecting primary data as a turbine model, and 2-dimensional object modeling.

#### 3.1 Research Sites

The modeling and simulation were conducted at the Ocean Structure System Laboratory, Marine Engineering Department, Faculty of Engineering, Hasanuddin University, Indonesia. The research area is in the North Sawu Sea Waters, East Nusa Tenggara, at position  $8^\circ54'18.4''S$ ,  $120^\circ44'44.6''E$ , which can be seen in Figure 2. This area is the most strategic because it has great wind potential for the development of Ocean Renewable Energy (ORE) based on [3]. In this area, an area with a sea depth limit of 100 m was chosen.



**Fig. 2.** Research sites

### 3.2 Data Collection

To complete the design, installation, and operation steps of offshore wind turbines safely and efficiently, it is essential to have meta ocean data (meteorology and oceanography) for the operational conditions of the installation. In this study, the research area used was the North Sawu Sea. This data includes average Wave Height ( $H_w$ ) as presented in Table 1. The floating wind turbine system used is the ITI Energy Barge model with its turbine set, specifically the NREL 5MW Baseline turbine model that data shown in Tables 2 and 3.

**Table 1.** North Sawu sea environmental data

Description	Value	Units
Average Wave Height	1	m
Wave Amplitude	0.5	m
Wave Frequency	1.08331	rad/s
Wave Period	5.8	s

**Table 2.** Main data of ITI energy barge structure

Description	Value	Units
Length × Width × Height	40 × 40 × 10	m
Draft	4	m
Freeboard	6	m
Volume Displacement	6,000	m <sup>3</sup>
Total Weight of Platform	5,452,000	kg

**Table 3.** NREL 5MW wind turbine data

Description	Value	Units
Power Capacity	5	MW
Blade Length	61.5	m
Tower Height	87.6	m
Rotor Diameter	126	m
Hub Diameter	3	m
Hub Height	90	m
Rotor Weight	110,000	kg
Nacelle Weight	240,000	kg
Tower Weight	347,460	kg
Tower Diameter Bottom	6	m
Tower Diameter Top	3.87	m
CoG turbine (X; Y; Z)	-0.2 , 0.0 , 64	m

### 3.3 Floater Structure Variation Modeling

In the simulation settings, each variation of the floater shape used will be carried out individually. Modeling of each variation of the floater structure is carried out with the help of Ansys SpaceClaim software based on the main geometry data of the ITI Energy Barge obtained. In this research, a variation of the comparative model was made with different geometric shapes, designed so that the displacement does not have too much difference. Then, modeling is carried out to obtain mass data for each geometry. In the modeling process, the object is modeled in 3 dimensions, with 2 main objects, namely the floater foundation at the bottom and the wind turbine structure at the top. Then, the floater dimensions are obtained as in Tables 4, 5, and 6.

**Table 4.** Cube floater data

Description	Value	Units
Length Floater	40	m
Width Floater	40	m
Height Floater	10	m
Draft	4	m
Displacement	6,560	ton

**Table 5.** Cylindrical floater data

Description	Value	Units
Floater Diameter	40	m
Height Floater	10	m
Draft	5.1	m
Displacement	6,569	ton

**Table 6.** NREL 5MW wind turbine data

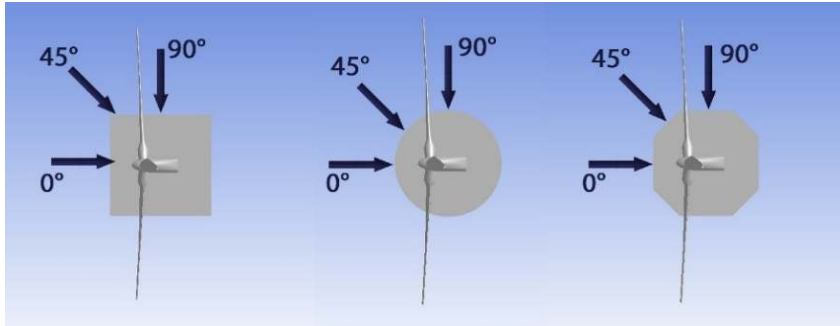
Description	Value	Units
Side Length Floater	20	m
Overall Beam Floater	40	m
Height Floater	10	m
Draft	4.57	m
Chamfer Beam	10	m
Displacement	6,557	ton



(a) Cube                      (b) Cylinder                      (c) Octagon

**Fig. 5.** Model floater design variations

In this research, 3 (three) variations of incoming wave directions were also used, namely heading wave (0°), quartering wave (45°), and beam wave (90°) as shown in Figure 6. After the overall structural shape modeling is carried out, the weight parameters are modeled using the Finite Element Method, with the help of Ansys Static Structural software by setting the materials used for each component, the floater with pontoon concrete material, and the turbine with Epoxy Carbon UD (230 GPa) Prepreg material.



**Fig. 6.** Variation in the direction of ocean waves

**Table 7.** NREL 5MW wind turbine data

Component	Weight Component		Difference (%)
	Product Data (kg)	Ansys Model (kg)	
Tower	347,460	346,950	0.15
Blade	17,740	17,648.8	0.52
Nacelle	240,000	238,243.8	0.74
Hub	56,780	56,582.7	0.35
Total Weight	697,460	694,720	0.39
Floater Weight	5,452,000	5,442,300	0.18
Full Platform	6,149,460	6,137,000	0.20

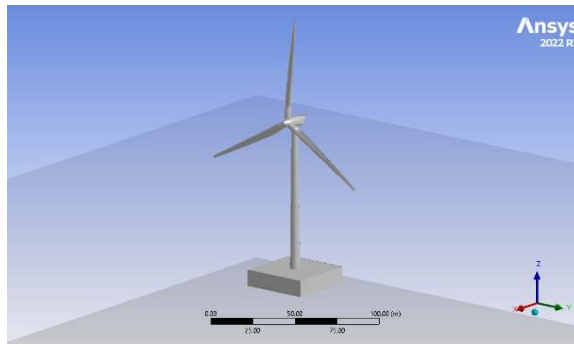
Because the design of other floater variation shapes refers to ITI Energy Barge floater data, and the turbine model used in other shape variations also uses the same model. Then the weight of the structure and the entire floater is obtained, with other shape variations as shown in Tables 8 and 9.

**Table 8.** Weight parameters of cylindrical turbine structure components

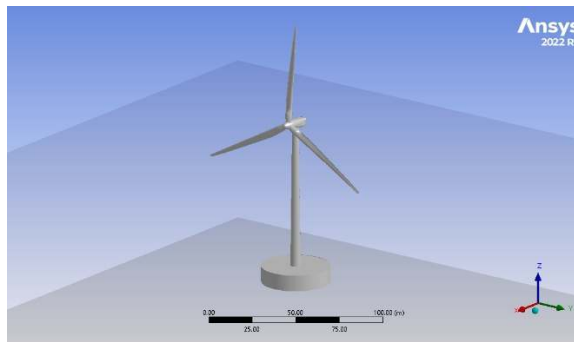
Component	Weight Component		Difference (%)
	Product Data (kg)	Ansys Model (kg)	
Floater Weight	5,452,000	5,408,800	0.80
Full Platform	6,149,460	6,103,600	0.75

**Table 9.** Weight parameters of octagonal turbine structure components

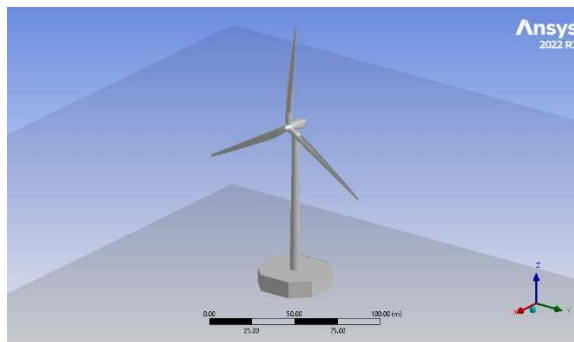
Component	Weight Component		Difference (%)
	Product Data (kg)	Ansys Model (kg)	
Floater Weight	5,452,000	5,432,300	0.36
Full Platform	6,149,460	6,127,100	0.36



**Fig. 7.** Overall view of the structure of the cube floater model



**Fig. 8.** Overall view of the structure of the cylindrical floater model



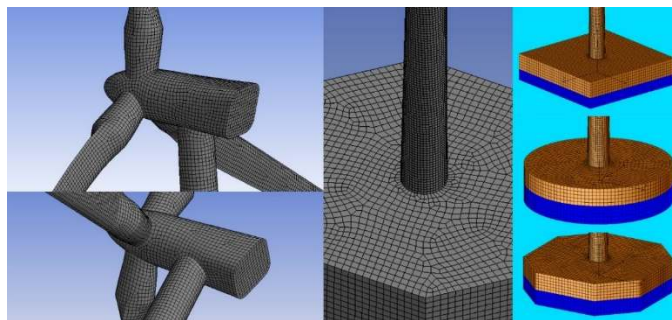
**Fig. 9.** Overall view of the structure of the octagonal floater model

From the results of the Analysis with the help of the Ansys Static Structural Program, the data that will be entered into the Ansys Aqwa Program is obtained. This data is in the form of the center of gravity and the moment of inertia of the entire structure. This value is very important in the Analysis because it will affect the motion response of the floating wind turbine structure when subjected to external environmental loads. This can be seen in Table 10.

The meshing process is carried out in the steps before entering the simulation result stage. The use of meshing element values in all forms of model variations uses the same value. After the mesh is generated, the maximum frequency field allowed will display the maximum wave frequency that can be included in the analysis of Hydrodynamic Diffraction [13].

**Table 10.** NREL 5MW wind turbine data

Floater Shape	Moment of Inertia (kg.m <sup>2</sup> )	CoG (m)
Cube	I <sub>xx</sub> = 4,795,000,000	X = -0.02340
	I <sub>yy</sub> = 4,777,800,000	Y = 0
	I <sub>zz</sub> = 1,975,200,000	Z = 8.820
Cylinder	I <sub>xx</sub> = 4,545,700,000	X = -0.02340
	I <sub>yy</sub> = 4,528,500,000	Y = 0
	I <sub>zz</sub> = 1,480,200,000	Z = 7.763
Octagon	I <sub>xx</sub> = 4,638,900,000	X = -0.02340
	I <sub>yy</sub> = 4,621,000,000	Y = 0
	I <sub>zz</sub> = 1,652,500,000	Z = 8.268



**Fig. 10.** Meshing surface shape of the resulting object

## 4 Results and Discussion

This simulation uses regular waves, where the structure experiences changes in position both translationally and rotationally. These changes are then presented in the form of a Response Amplitude Operator (RAO) curve because the RAO curve is formed by two parameters, namely the magnitude of the floating structure response to the frequency of the incident wave. In this simulation, 3 directions of wave arrival are used, namely from the head wave (0°), quartering wave (45°), and beam wave (90°). The parameters of the sea waves used are the 5-year wave height in the waters of the North Sawu Sea, which is 1 m with an amplitude of 0.5 m. The frequencies used are 0.1 rad/s to 2.30 rad/s.

**Table 11.** Ocean wave parameters

No.	Wave Frequency (Rad/s)	Period (s)
1	0.10	60.93
2	0.34	18.04
3	0.59	10.59
4	0.83	7.49
5	1.08	5.80
6	1.32	4.73
7	1.57	3.99
8	1.81	3.45
9	2.06	3.04
10	2.30	2.72

In the coupled motion response analysis, the head wave direction this time is carried out at 0° and produces a Response Amplitude Operators (RAO) curve, namely the 2 degrees of freedom coupled motion.

### 4.1 Analysis of Floater Motion Response in Head Wave Direction (0°)

The analysis of the motion response on regular waves can be seen in 2 degrees of freedom from the three variations of the structure. The result is a Response Amplitude Operator (RAO) curve at 2 degrees of freedom of Heave-Pitch. These three directions of motion will be reviewed in pairs (coupled) in 2-dimensional conditions. Then, the comparison process is carried out by comparing the RAO value from the Ansys simulation with the calculation analysis using the Maxsurf software. Then, the comparison to ensure the RAO value is correct is carried out in the direction of free motion that has the highest value among the three forms of floaters.

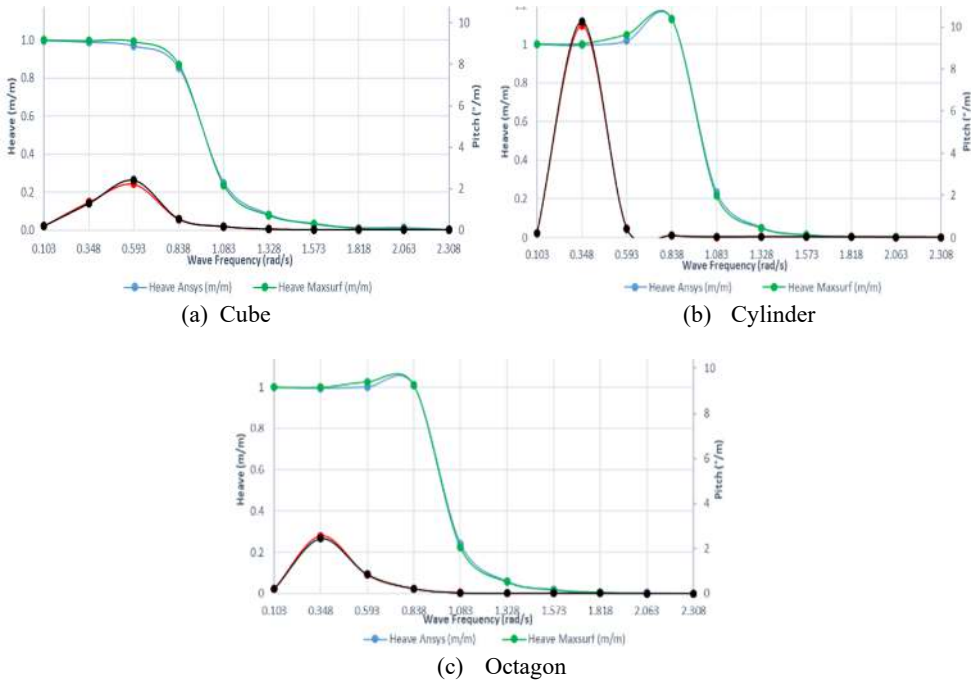
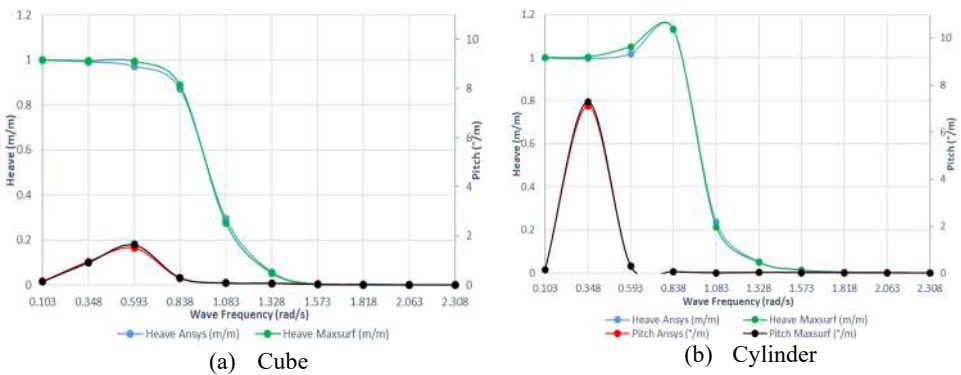


Fig. 11. Heading wave responses

### 4.2 Analysis of Floater Motion Response in Quartering Wave Direction (45°)



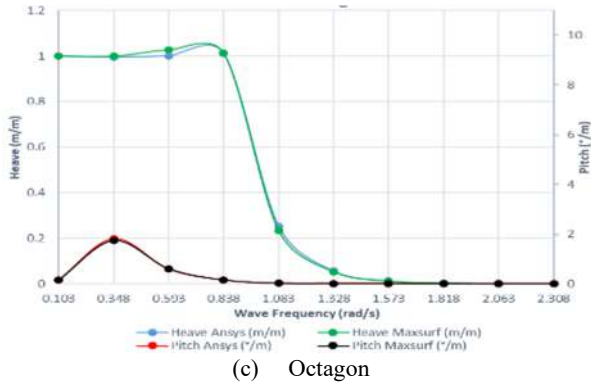


Fig. 12. Quartering wave responses

### 4.3 Analysis of Floater Motion Response in Beam Wave Direction (90°)

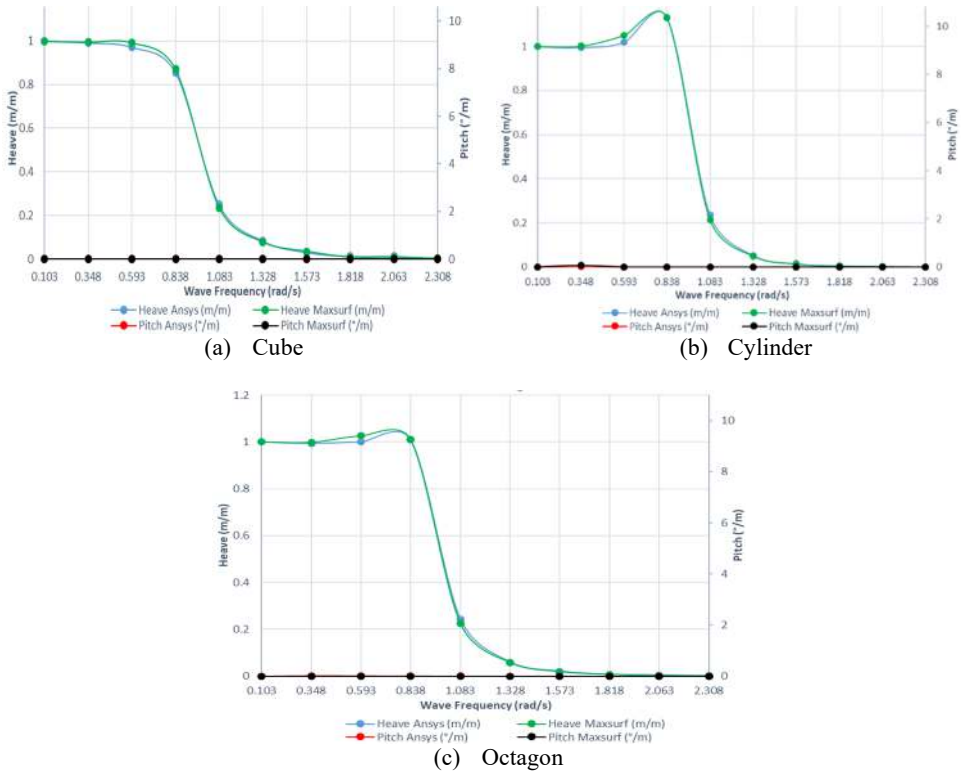
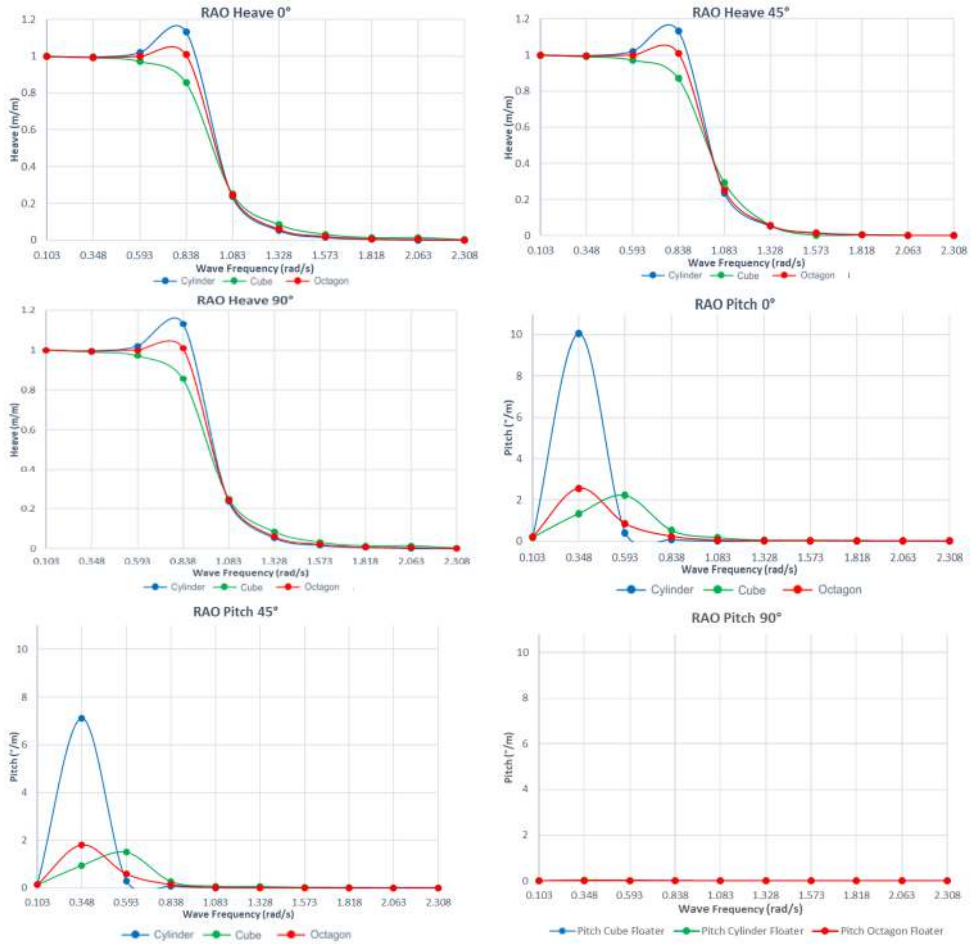


Fig. 13. Beam wave responses

### 4.4 Comparison Floater Variation Motion Response



**Fig. 14.** Motion responses

In the response value results obtained, the three forms of floaters have almost the same heave motion response value to the 3 directions of incoming waves used. In addition, also in the sub-critical area, most of the responses of the three floaters are almost the same as the wave height value used. This is because at low frequencies starting from a frequency of 0.103-0.348 rad/s, with a wave height of 1 m, the response value produced will be the same as the wave height value. This is because in this frequency range, the floater will move following the pattern or contour of the long wave elevation so that the amplitude of the movement will be more or less the same as the wave amplitude.

Meanwhile, the critical area (peak of the curve) is at a frequency of 0.583-0.838 rad/s. The peak of the curve is at the natural frequency, which is the resonance area, so that the movement response is magnified, or the amplitude of the movement will be several times greater than the wave amplitude. It can be seen in the RAO curve image that the cylindrical and octagonal floaters have a response that exceeds the wave height, while the cube floater is actually lower. This is because the cube shape has a good response and is more stable when facing sea waves. In addition, the influence of the volume of the cube floater, which tends to be larger than other floater shapes, also plays an important role.

Meanwhile, a frequency of 1.328 to 2.308 rad/s is a supercritical area of RAO, where all three forms of floaters experience a significant decrease in response; this is because this frequency includes having short wave values (with periods). In this area, the movement response will decrease. The higher the frequency, or the denser the successive wave crests, the more it will give an effect like a sea structure moving on relatively flat water.

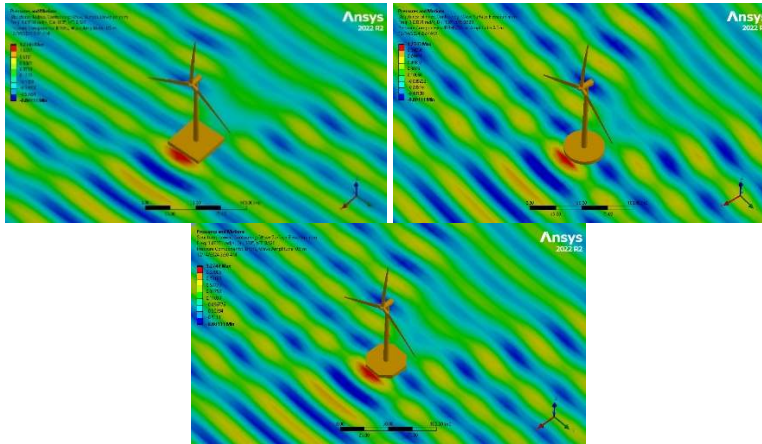
Likewise, with the Pitch motion response above, the cylindrical floater shape has the highest response value in the  $0^\circ$  direction followed by the  $45^\circ$  direction, while in the  $90^\circ$  direction, all the analyzed floater shapes do not respond to the pitch motion, this is because the pitch motion is not too affected by the waves coming from the side. If reviewed again from the RAO curve of the pitch motion, the peak response of the cylindrical and octagonal pitch motion is at a frequency of 0.348 rad/s, while the cube pitch motion is at a frequency of 0.593 rad/s. The difference in peak position is because the peak response of the motion is always at the natural frequency of a structure. Where this frequency is included in the resonance area of the structure, so that the pitch motion response will also be several times greater than the wave slope.

When viewed from all values and Response Amplitude Operator (RAO) curves of 2 heave-pitch motions in a coupled manner, the cylindrical floater has the highest response among the other three floaters, followed by the octagonal floater. The best response among the three forms is the cube-shaped floater. This is because the geometric shape of the floater affects the volume and area of the waterline of each floater because the cylindrical floater has a volume that tends to be smaller with the smallest area of the waterline than the other two forms. When comparing the response values in each direction of motion reviewed in pairs (coupled), the heave motion in the three floater forms has a difference in value that is not too far apart. This is because the displacement and total weight designed in the floater form also have differences that are not too different.

When viewed from both directions of incoming waves, both free heave-pitch motions are coupled and have their own characteristics. In the heave motion, the response value of each floater form has a value difference that is not very different in each direction. Meanwhile, pitch motion has a significant difference between the directions of the other wave arrivals. Where in the pitch motion, the direction of  $90^\circ$  has the lowest value because the response value is almost 0, followed by the direction of  $45^\circ$  then the highest value in the direction of  $0^\circ$ . While in the heave motion, the response values of the three floater forms have differences that are not too significant. In addition, at the simulation setting stage, the use of mesh elements in the Ansys Aqwa and Maxsurf motion programs is different, where the elements produced in the maxsurf motion program are fewer than Ansys Aqwa, because the maxsurf motion program limits the number of elements used in performing motion response analysis. This, of course, will make the number of element sizes in the 3D panel model formed also different. Apart from that, the motion response values of the two software used still have a value difference that is not too far apart so that the results of the analysis can be accepted.

#### **4.5 Comparison Wave Field**

From the image above, we can see the waveform that occurs when ocean waves pass through the floater structure from the  $0^\circ$  direction. In the cube floater, the waves are held back by the flat surface at the front of the floater. This also creates a fairly high wave increase along the front side of the floater. So that the waves diffracted behind the cube floater and looked lower. Cylindrical floaters tend to separate waves towards the edge of the floater because of their curved shape, without any flat area to hold back incoming waves. While the octagonal shape is almost similar to a cube, the flat area in front of the floater only holds back the lowest incoming wave, while the sloping side separates the waves in two directions.



**Fig. 15.** 3D view of the wave field

## 5 Conclusion

The response of the motion of the offshore floating wind turbine structure is important to analyze, especially in determining the shape of the surface of the floater foundation used for the barge type. From the results of the analysis that has been carried out, the following conclusions can be drawn.

1. The motion response of each floater variation, namely the cube floater, has a maximum motion response value, namely a heave motion of 0.999 m/m and a pitch motion of 2.228 °/m. Meanwhile, the cylindrical floater has a heave motion of 1.132 m/m and a pitch motion of 10.050 °/m. Then, the octagon floater, at a heave motion of 1.010 m/m and a pitch motion of 2.565 °/m.
2. The cube form is the floater shape with the lowest reaction, followed by the octagon shape, while the cylindrical shape has the maximum response over all motion orientations and wave directions. This is because the cylindrical shape has a curved surface around it, and a smaller volume.
3. The floating barge floater shape is the best in terms of economy, and planning a floater with a large volume certainly helps the floater maintain its position when experiencing environmental loads.

However, because the present study only considered 2D motions, it is suggested the future study could consider 6 DOF motions.

## References

1. P.J. Tavner, *Offshore wind turbines: reliability, availability and maintenance* (Institution of Engineering and Technology, 13th ed., 269) (2012).
2. P3TKEBTKE, *Potensi Energi Angin Indonesia 2020* (Badan Layanan Umum Pusat Penelitian, Dan Pengembangan Teknologi Ketenagalistrikan, Energi Baru Terbarukan, Dan Konservasi Energi) (2021). [https://p3tkebt.esdm.go.id/pilot-plan-project/energi\\_angin/potensi-energi-angin-indonesia-2020](https://p3tkebt.esdm.go.id/pilot-plan-project/energi_angin/potensi-energi-angin-indonesia-2020).
3. N.P. Purba, J. Kelvin, R. Sandro, S. Gibran, R.A.I. Permata, F. Maulida, M.K. Martasuganda, *Energy Procedia* 65, 230-238 (2015). <https://doi.org/10.1016/j.egypro.2015.01.035>.

4. M. Karimirad, *Offshore Energy Structures* (2014). [https://doi.org/10.1007/978-3-319-12175-8\\_3](https://doi.org/10.1007/978-3-319-12175-8_3).
5. F. Mahmuddin, M. Kashiwagi, *Proc. Int. Offshore Polar Eng. Conf.* 1263-1270 (2012), Rhodes Island, Greece.
6. F. Mahmuddin, M. Kashiwagi, *Proc. Int. Offshore Polar Eng. Conf.* 1271-1278 (2012), Rhodes Island, Greece.
7. E.E. Bachynski, *Offshore Wind Energy Technology* (John Wiley & Sons Ltd, First Edit, 103-142) (2018). <https://doi.org/10.1002/9781119097808.ch4>.
8. A.N. Robertson, J.M. Jonkman, *Proc. Int. Offshore Polar Eng. Conf.* 443-450 (2011).
9. M. Philippe, A. Babarit, P. Ferrant, *Renewable Energy* 49, 151-155 (2013). <https://doi.org/10.1016/j.renene.2012.01.042>.
10. T. Choynet, S. Vasseur, *Performance and Mooring Qualification in Floatgen, Grand Renewable* (2019).
11. N.F. Firdaus, E.B. Djatmiko, R.W. Prastianto, M.F. Ismail, *Wave: J. Ilmiah Teknol. Maritim* 15, 31-44 (2021).
12. R. Bhattacharyya, *Dynamics of marine vehicles* (E.M. McCormic (ed.), A Wiley-Interscience Publication) (1978).
13. ANSYS, *Aqwa Theory Manual* (Issue July) (2022).